RESEARCH CIRCULAR 249 APRIL 1979

Drainage Investigations of the Cultivated Willard Marsh Soils

S. S. HUNDAL

G. S. TAYLOR

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
U. S. 250 and Ohio 83 South
Wooster, Ohio

CONTENTS

* * * *

AGDEX 507-555-752

4-79-2.5M

DRAINAGE INVESTIGATIONS OF THE CULTIVATED WILLARD MARSH SOILS

S. S. HUNDAL and G. S. TAYLOR[1]

INTRODUCTION

There are nearly 50,000 hectares of organic soils in Ohio. These soils are derived from organic deposits that accumulated in former lakes and ponds in northern Ohio.

The present investigations were carried out in the cultivated area of the Willard Marsh located near the town of Celeryville (Fig. 1). This area covers nearly 50 square kilometers and is the center of the state's most concentrated fresh vegetable production area. These soils are highly productive and are used under an intensive management system for the production of celery, lettuce, onions, carrots, radishes, and potatoes. They were brought under cultivation some 30-50 years ago. The depth of the organic layer varies from less than 30 cm in some cultivated areas to about 5 meters in the virgin areas. Most of the cultivated area has an organic layer which is 1 to 2 meters deep. It is underlain by a greyish-blue clay which restricts vertical movement of water.

The cultivated organic soils of the Celeryville area are poorly drained. Subsurface drainage is essential for intensive crop production and is practiced almost universally in this area. The area is drained by a network of large open ditches and subsurface drains. The ditches also serve as a channel for supplying irrigation water from an upland reservoir. Water table control is practiced on some fields by subirrigation through drains.

During the last few years drainage has been impaired at some locations due to accumulations of iron sludges (ochre) and organic fibers inside the drains. In severe cases the drains have become clogged and must be cleaned or replaced by a new installation. Ochre accumulation in drains is becoming more widespread with time and some problem areas are becoming more acute.

In 1974 research investigations were initiated at Celeryville to characterize the nature of the drain sediments and to evaluate factors associated with their accumulation. Observations were also made on the performance of drains after they were jetted to remove sediments.

[1]Post-doctoral Research Associate in Agronomy and Professor in Agronomy, respectively, The Ohio State University and Ohio Agricultural Research and Development Center. The authors express appreciation to the Corrugated Plastic Tubing Association and to the muck crop growers (Stambaugh Farms, Buurma Brothers Farms, Wier Brothers Farms, and Holthouse Brothers Farms) of Celeryville, Ohio, for partial financial support of this project.

EXPERIMENTAL SITES

The soils at all sites are classified as Mesic Medisaprists. They have a plow layer that is black in color, highly decomposed, and without distinguishable plant fibers. The subsoil is a partially decomposed, reddish-brown muck. Subsurface drains are usually installed in this layer. Four sampling sites were selected which were subject to frequent ponding and indicative of having inadequate subsurface drainage. The drainage systems at these four sites were as follows:

Site 1 was located at Buurma Brothers Farm. Ten-centimeter diameter, corrugated plastic drains were installed at this site some 5 years previous to the study. The drains had 1.90 by 0.16 cm slotted openings, an average depth of 0.8 m, and were spaced 15 m apart. All drains at this site were essentially free of sediments in 1974.

Site 2 was located at Stambaugh's Farm. Ten-centimeter diameter, clay tile drains were installed at this site some 25 years previous to the study. These drains had about 0.95 cm crack spacing, an average depth of 0.7 m, and were spaced 15 m apart. All drains were one-half to three-fourths filled with a mixture of black organic soil and reddish-brown ochreous sediments (Fig. 2A).

Site 3 was located at Wier Brothers Farm. Ten-centimeter diameter, clay tile drains were installed at this site some 20 years previous to the study. The drains had 0.95 cm crack spacing, an average depth of 0.8 m, and were spaced 15 m apart. These drains were about 90% filled with black organic sediments (Fig. 2B). In addition to clay tile drains, 10-centimeter diameter plastic drains were installed midway between the clay drain lines about 5 years previous to the study. The plastic drains had 1.9 cm diameter round openings and were installed at an average depth of 0.9 m. These drains contained a 1 cm layer of black organic sediments. The sediments just covered the valleys in the corrugations, and this is a typical condition for drains at these sites.

Site 4 was located at Holthouse Brothers Farm. Ten-centimeter diameter, clay tiles were installed at this site some 15 years previous to the study. The drains had about 0.95 cm crack spacing, an average depth of 0.5 m, and were spaced 15 m apart. These tile drains were approximately one-third filled with black organic sediments (Fig. 2C).

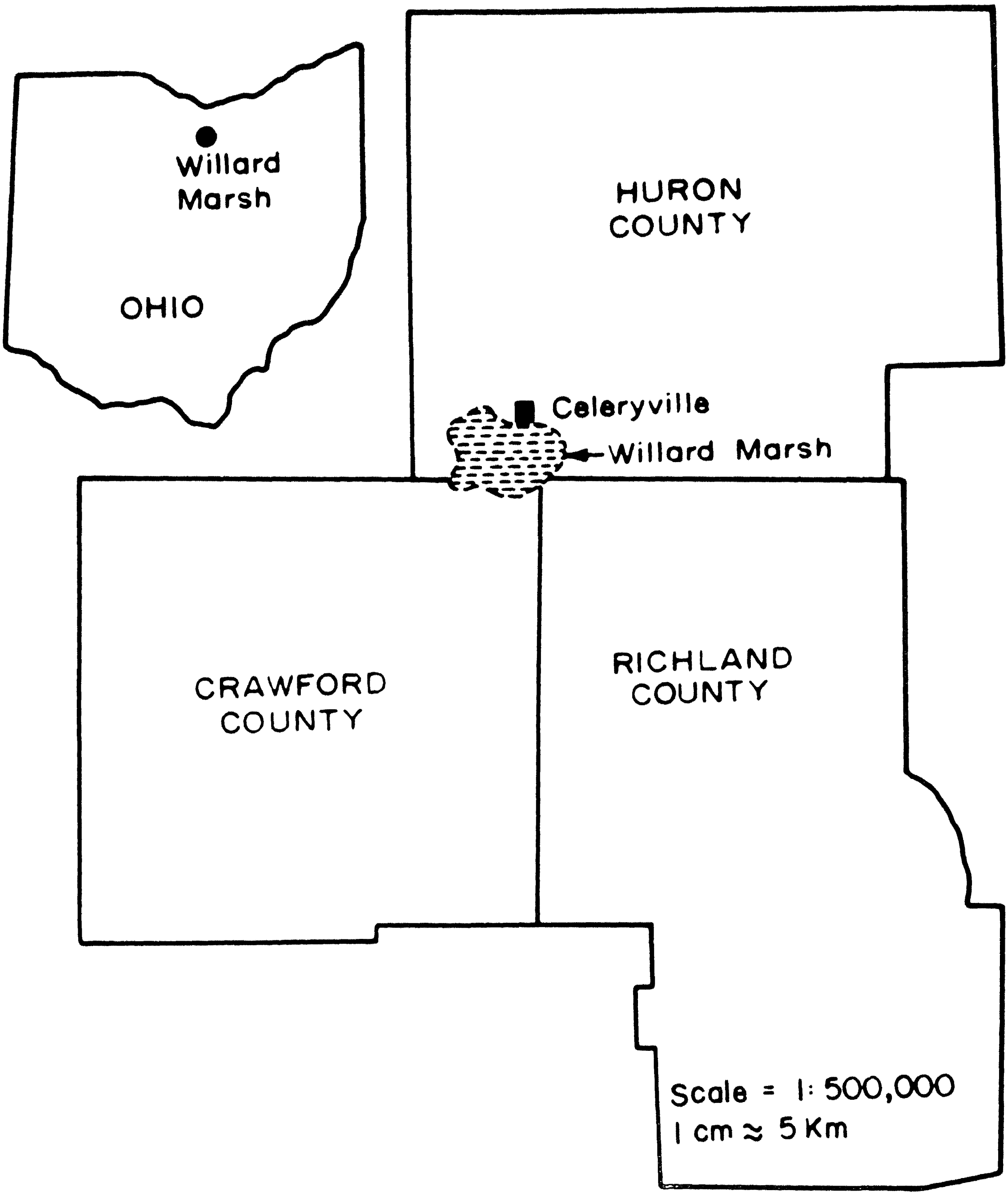

FIG. 1.—Location of Willard Marsh in North Central Ohio.

FIG. 2A.—Section of tile drain from Site 2. These drains are approximately three-fourths filled with a mixture of organic soil and reddish-brown, ochreous sediments.

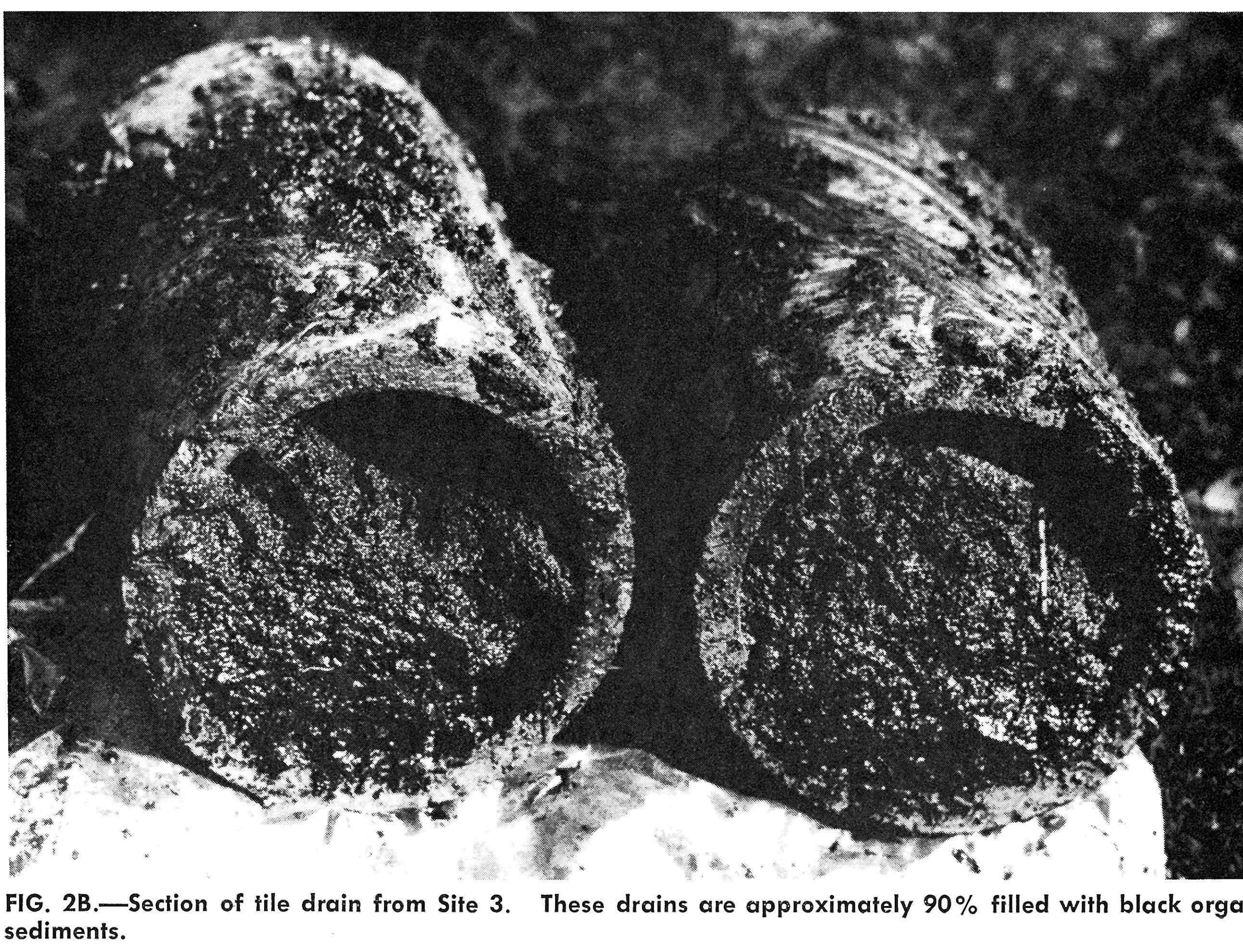

FIG. 2B.—Section of tile drain from Site 3. These drains are approximately 90% filled with black organic sediments.

FIG. 2C.—Section of tile drain from Site 4. These drains are approximately one-third filled with black organic sediments.

METHODS AND MATERIALS

Soil Physical Properties

Bulk density and moisture retention were determined on 7.6 by 7.6 cm soil cores taken from Site 2. Soil moisture content at 15-bar suction was determined on disturbed soil samples using a pressure plate extractor. The plasticity limits of the surface soil were determined using the standard procedures. Hydraulic conductivity of the soils was determined in the field by using the auger hole technique (8). A shallow-well pump-in technique was employed for measurements of hydraulic conductivity above the water table (2).

Chemical Characterization of Soil and Drain Sediments

On-site inspection of the drains was made by exposing sections of drain lines. The drains were inspected for accumulation of sediments and sealing of tile joints and drain openings. Samples of drain sediments and drainage water were collected for laboratory analysis. Soil samples were collected from various depths at the four sites. These were kept at field moisture content in air tight plastic bags stored at 4° C until the time of analysis. The following chemical analyses were made on these samples:

Degree of Decomposition. As a means of assessing the relative degree of decomposition of soil from different sites, a colorimetric method was used similar to Levesque and Danel (7). A 1.0 g of air dry sample was extracted with 100 ml of 0.025 M sodium pyrophosphate solution following 18 hours of equilibration at room temperature. The optical density of a 50-times diluted extract was measured with a spectrophotometer by recording the absorbance readings at 465 mμ wave length.

pH. The pH of soil at field moisture content was determined using a soil to water ratio of 1:1 on a volume basis.

Mineral Content. An oven dry sample of the soil was ignited in a muffle furnace at 450° C for 24 hours. The residue remaining after ignition was considered to be the mineral content. The organic matter content was given as the weight loss during ignition.

Total Carbon and Nitrogen. Total carbon was determined by the dry combustion technique while

TABLE 1.—Physical Characteristics of Three Organic Soil Horizons from Site 2, Celeryville, Ohio.

Sampling Depth, Horizon, and Color	Bulk Density (g/cm³)		Plasticity Constants (%)	
	Oven-dry Basis	Field Moisture Basis	Plastic Limit	Liquid Limit
0-30 cm Sapric, black	0.41	1.12	160	213
30-70 cm Hemic, reddish-brown	0.18	0.95	NP*	NL†
70-100 cm Hemic, brownish-gray	0.14	1.04	NP	NL
	Soil Moisture at Sampling	Saturation Moisture	0.1-bar Moisture	15-bar Moisture
		(Percent by Volume)		
0-30 cm Sapric, black	71	76	71	41
30-70 cm Hemic, reddish-brown	80	87	74	26
70-100 cm Hemic, brownish-gray	91	95	81	20

*NP—Soil does not show plastic property
†NL—Soil does not show liquid property.

total nitrogen was determined by the Kjeldahl procedure.

Chemical Composition. A 0.1 g of soil was treated in HNO_3 followed by digestion in a mixture of $HClO_4$ and HF. The extract was analyzed for Fe, Mn, Al, Ca, Mg, Na, and K on an atomic absorption spectrophotometer.

$AlCl_3$-extractable Iron. The reduced iron in soil was determined according to the method proposed by Ignatieff (6). A sample of field moist soil was extracted with a 2% solution of $AlCl_3$ at pH 3.3. The extract was analyzed for Fe^{2+} by developing the color with orthophenanthroline.

Particle Size Analysis. After destroying the organic matter with H_2O_2, the remaining mineral fraction was separated into sand, silt, and clay size separates using the standard pipette method.

RESULTS AND DISCUSSION

Soil Physical Properties

The data in Table 1 show that the dry bulk density of the highly decomposed plow layer is two to three times greater than that in the partially decomposed subsoil layers. Several factors may contribute to the greater density of the surface soil. The surface soil usually has a higher decomposition state, resulting in increased mineral content per unit volume of the soil. Also, subsidence and compaction by tillage machinery often result in compaction of the surface soil. The wet bulk densities for all horizons are essentially the same, indicating an increase in moisture content with depth. The plastic limit for the surface layer ranges from 156 to 163% for the four sites, with a mean value of 160%. The liquid limit for the surface layer ranges from 178 to 266%, with a mean value of 213%. No distinct plastic or liquid properties can be noted for the subsoil horizons.

The data in Table 2 show the soil hydraulic conductivity at three of the sites. Each mean represents a minimum of five separate auger hole measurements. The plow layer shows the greatest conductivity. The conductivity of this layer is subject to considerable variability during the year because of tillage operations, equipment traffic, freeze-thawing, and wetting

TABLE 2.—Soil Hydraulic Conductivity of Sites 1, 2, and 3 as Determined by the Auger Hole Method, Celeryville, Ohio.

Location	Depth	Hydraulic Conductivity		Coefficient of Variation
		Mean	Range	
	(cm)	(cm per hour)		(%)
Site 1	0-30	2.23	0.96-4.14	36
	30-70	0.38	0.28-0.58	31
	70-100	0.38	0.15-1.14	69
Site 2	0-30	2.13	1.02-2.77	30
	30-70	0.28	0.10-0.56	55
	70-100	0.10	0.03-0.25	62
Site 3	0-30	1.65	0.79-3.02	40
	30-70	0.25	0.18-0.36	30
	70-100	0.05	0.03-0.18	70
Means	0-30	2.00	0.79-4.14	35
	30-70	0.30	0.10-0.58	39
	70-100	0.18	0.03-1.14	67

and drying. Because of low structural stability of the ground surface in cultivated soils, the upper 1 centimeter often has hydraulic conductivities less than 0.05 cm per hour. These same processes bring about much smaller changes in physical conditions of the subsoil layers. The subsoil at all sites has a low conductivity, all mean values being less than 0.4 cm per hour. Subsurface drains are practically always installed in this subsoil layer. Based on observations of undisturbed sites recently brought into cultivation, the conductivity of the subsoil layer at the three sites appears to have decreased manyfold since these soils were put under cultivation. The decrease in hydraulic conductivity of the subsoil in cultivated areas is the result of increased oxidation and subsidence upon drainage and of soil compaction which has occurred under intensive management over several decades. Among these two, soil compaction appears to be the most significant factor.

Chemical Characterization of Soil and Drain Sediments

The optical density data for the soil extracts are shown in Table 3. It reflects the relative degree of decomposition for soils at the four sites. A higher optical density reading generally means a greater degree of decomposition. A comparison of the data indicates no significant differences among Sites 2, 3, and 4. Site 1 shows the least amount of decomposition at all depths. The soil at Site 1 is a deeper muck and was brought under cultivation about 20 years later than at the other sites. At all sites the decomposition usually shows a decrease with depth but significant differences are apparent only for the lower depths. Visual observations made at the time of taking field soil samples agree with the general trend of decomposition noted here from laboratory analysis.

The data in Table 4 give the pH and selected chemical analyses of the soil plow layer (0-25 cm) and subsoil (25-75 cm). A higher pH was found in the plow layer than in the subsoil, probably as a result of lime applications over the years. The data show a lower organic content (and thus a higher mineral content) in the plow layer than in the subsoil. This increase in mineral content occurs as a result of oxidation of the organic plant materials. Higher state of decomposition in the plow layer is

TABLE 3.—Optical Density of Sodium Pyrophosphate Treated Soil Extracts from the Four Sites, Celeryville, Ohio.

Sampling Depth, cm	Optical Density of Extract* (465 $m\mu$)				LSD, Sites (0.05)
	Site 1	Site 2	Site 3	Site 4	
0-25	0.07	0.17	0.17	0.16	0.04
25-75	0.07	0.13	0.16	0.14	0.04
75-100	0.04	0.09	0.08	0.09	0.04
LSD, Depths (0.05)	0.03	0.03	0.03	0.03	

*Each value is a mean of six soil samples. A higher optical density value indicates greater degree of decomposition.

TABLE 4.—Chemical Composition of Soil from the Four Sites at Celeryville, Ohio. The Elemental Composition Represents Total Amounts Present in the Soil.

Site	Depth, cm	pH	Organic Content	Fe	Al	Mn	Ca	Mg	Na	K
			Percent by Weight							
1	0-25	6.3	80	1.0	0.9	0.02	3.0	2.0	2.9	1.9
	25-75	5.5	90	0.7	0.6	0.01	2.4	1.5	2.6	1.5
2	0-25	4.9	81	2.0	1.1	0.02	2.5	1.3	2.0	1.2
	25-75	4.7	88	1.5	0.9	0.01	2.0	1.1	1.7	1.1
3	0-25	5.7	70	1.6	1.3	0.03	2.7	1.0	2.7	0.8
	25-75	5.0	81	1.6	1.1	0.01	2.2	0.4	1.7	0.5
4	0-25	5.7	78	1.6	1.0	0.03	3.6	1.3	3.3	1.3
	25-75	5.2	84	1.7	0.8	0.02	2.8	1.1	3.1	1.6
Means	0-25	5.7	77	1.6	1.1	0.02	3.0	1.4	2.7	1.3
	25-75	5.1	86	1.4	0.9	0.01	2.4	1.0	2.3	1.2

TABLE 5.—Chemical Composition of Drain Sediments from Sites 2, 3, and 4 at Celeryville, Ohio.

Sample Number*	Organic Content	Fe	Mn	Al	Ca	Mg	Na	K	N	C	C/N Ratio
		Reddish-brown Ochreous Sediments—Percent by Weight									
Site 2											
a	51	23	0.04	2.1	4.5	5.2	5.1	2.0	2.0	30.3	15.1
b	45	18	0.02	—	1.8	0.3	0.6	0.2	0.9	20.6	22.9
c	63	9	0.03	2.0	2.3	2.3	3.0	1.2	1.4	24.8	17.7
d	46	19	0.01	—	1.4	0.2	0.1	0.2	0.7	20.8	29.7
e	44	10	0.01	—	0.9	0.2	0.3	1.0	1.0	22.1	22.1
Mean	50	16	0.02	2.0	2.2	1.6	1.8	0.9	1.2	23.7	21.5
		Black Organic Sediments—Percent by Weight									
Site 3	71	2	0.02	1.9	3.8	1.6	2.5	1.4	1.4	36.9	26.4
Site 4	78	2	0.04	1.2	5.2	3.5	4.0	1.8	1.9	40.4	21.3
Mean	75	2	0.03	1.5	4.5	2.6	3.3	1.6	1.7	38.6	23.8

*Samples a to c are from 25-year-old tile drains and samples d and e are from 1-year-old plastic drains at Site 2. There were no sediments in drains at Site 1.

reflected in higher amounts of Fe, Mn, Al, Ca, Mg, Na, and K than was found in the 25-75 cm depths. This is apparently a result of loss of carbon as CO_2 upon oxidation of plant materials and consequent accumulation of mineral elements in the residual matter. The concentration of these mineral elements is quite similar at the four sites. This suggests that organic soils at these sites probably originated from the same type of plant materials.

The chemical composition of drain sediments is shown in Table 5. Drain sediments are grouped into two categories on the basis of color and composition. All sediments are a mixture of organic matter and mineral materials. The reddish-brown, ochreous sediments show relatively large amounts of iron, ranging from 10 to 23% on a dry weight basis. In contrast, the iron contents in the soil are less than 2% (Table 4). Sediments from the drains do not contain large concentrations of manganese and aluminum, indicating that they do not play significant roles in sludge formation in these soils. The black organic sediments have nearly the same iron and total mineral content as the soil. Apparently these sediments are soil materials which accumulated as a result of unprotected surface inlets, physical obstruction to drain flow, or lack of sufficient grade.

The carbon/nitrogen ratio in the sediments was determined to see whether the sediments are composed mainly of bacterial residues or soil materials. The carbon/nitrogen ratio of reddish-brown ochreous sediments is approximately the same as in black organic sediments and ranges from 15 to about 30. These carbon/nitrogen ratios are wider than is usually the case in bacterial residues. Similar C/N ratios were reported by Petersen (9) from an analysis of 21 ochreous samples.

The pH and iron contents in the water samples taken from subsurface drains and seepage pits are given in Table 6. These pits were about 30 cm in diameter and extended to drain depth. Water could

TABLE 6.—Iron Content and pH of Water from Subsurface Drains and Seepage Pits at the Four Sites, Celeryville, Ohio.

Site	Iron (ppm)	pH	Comments
	Water from Drain Lines		
Site 1	2.0	6.0	Plastic drain
Site 2	5.0	5.0	Plastic and clay tile drains
Site 3	1.6	6.3	Clay tile drain
Site 4	1.5	6.0	Clay tile drain
Range	1.5-5.0	5.0-6.3	
	Water from Seepage Pits		
Site 1	0.6	5.8	0.6 m from drain
Site 2	2.5	5.3	0.6 m from drain
Site 3	0.8	6.2	Midway drains
Site 4	0.5	5.8	Midway drains
Range	0.5-2.5	5.3-6.2	

TABLE 7.—Organic Matter Content and Particle Size Distribution of the Mineral Fraction in Soil and Drain Sediments from Sites 2, 3, and 4 at Celeryville, Ohio.

Site	Organic Content	Mineral Content	Particle Size Distribution of Mineral Fraction: Sand	Silt	Clay
		Percent			
		Backfill Soil			
Site 2	77	23	3.4	61.4	35.2
Site 3	71	29	2.8	62.9	34.3
Site 4	77	23	1.7	76.4	21.9
		Drain Sediments			
Site 2	63	37	1.9	59.3	38.8
Site 3	71	29	4.1	49.8	46.1
Site 4	78	22	4.1	75.9	20.0

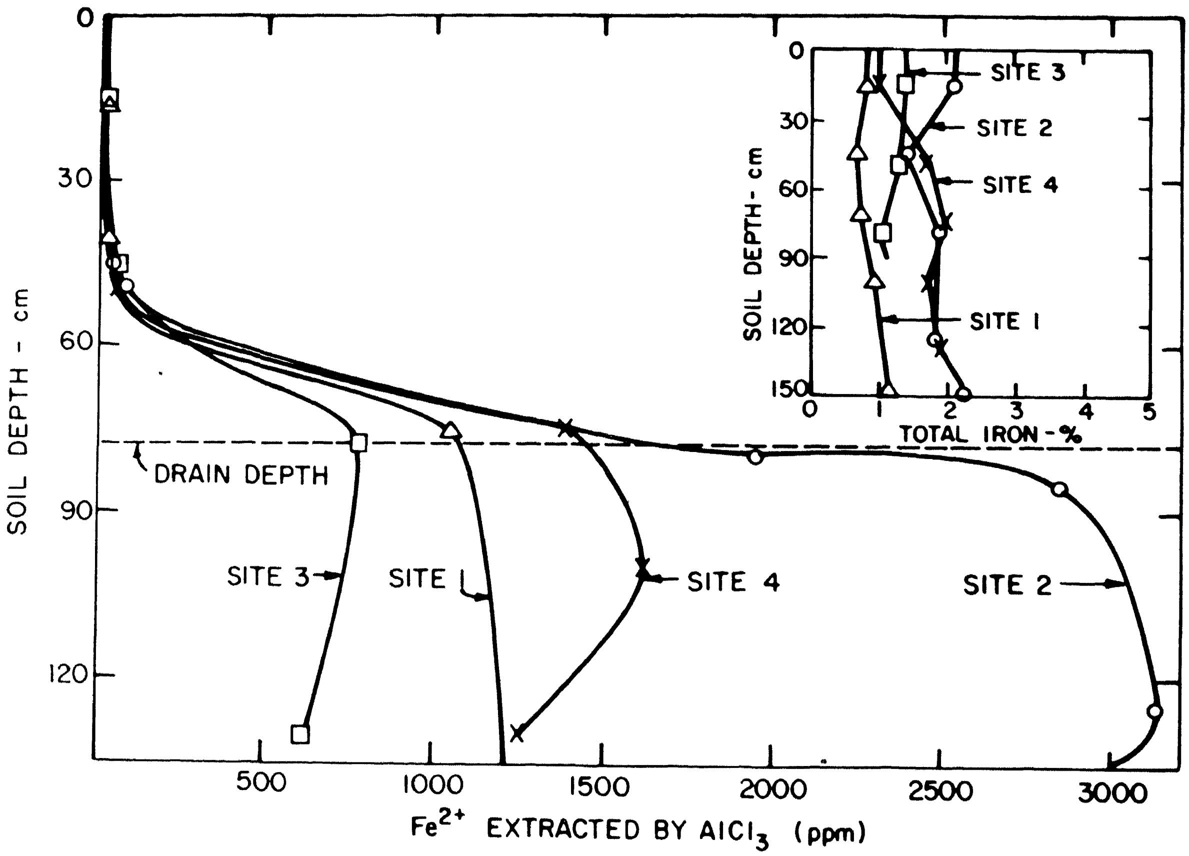

FIG. 3.—Total and ferrous iron extracted from the four sites at Celeryville, Ohio.

seep into the pits from the sides and the bottom and they served as observation wells for detecting water table elevations. All water samples show iron contents greater than 0.5 ppm. Ford (3) suggested iron concentration of this magnitude to be the lower limit for ochre formation. The water from drain lines at Site 2 was collected at various times during the year and shows a range in iron content from 2 to 15 ppm.

The distribution of total and reduced iron in soil at the four sites is shown in Figure 3. These graphs show that the total iron contents are similar throughout the soil profile and are in the range of 1 to 2%. The ferrous iron extracted by $AlCl_3$ is very low in the surface 60 cm depth, apparently because this layer is aerated for most of the year. The reduced iron contents below drain depth are quite large, seemingly a result of prolonged anaerobic conditions. Differences among the four sites reflect the frequency of wet soil conditions at these sites. Site 2 contains two to four times more Fe^{2+} than the other sites and has a severe ochre problem. Similar observations were made by Spencer *et al.* (10). They reported that the relative amounts of ochre formation at various locations in Florida citrus groves were in the same proportion as the amounts of reduced iron extracted from the soil with an aluminum chloride solution.

The amount and particle size distribution of the mineral fraction in the drain sediments and soil surrounding the drains are shown in Table 7. The sediments from the drains show about the same mineral content as found in the soil surrounding the drains. An exception is noted at Site 2. A higher mineral content in drain sediments at Site 2 is primarily due to accumulation of iron sludges in the drains at this site. The particle size distribution of the mineral fraction in the drain sediments is generally proportional to that in the soil surrounding the drains. About 95% of the mineral fraction is composed of silt and clay size particles.

MECHANISM OF OCHRE FORMATION AND ACCUMULATION IN DRAINS

In the absence of oxygen, the anaerobic soil environment existing under excess moisture favors microbial reduction of soil iron from ferric to ferrous form. The ferrous iron is transported to the drains in solution with the drainage water. An idealized model to explain the movement of iron-rich water toward subsurface drains was proposed by Hundal *et al.* (5). The model suggests that as the water table recedes below the ground surface, an increasingly greater proportion of flow entering the drain passes through the soil region lying below drain depth. Large amounts of soluble iron are usually present below the drain depth (Fig. 3). Thus ochre accumulation in drains will be greater during periods when water table is deeper because the water entering drains will be richer in iron and the drain flow rate will be so low that sludges may not be flushed from the drains in suspension.

The deposition of ochre in drains is generally believed to result from oxidation and precipitation reactions of iron. The iron in drains may exist in both inorganic and organic combinations. The mechanism of iron precipitation is a complex process and depends on the nature of microorganisms involved and environmental conditions (11). Changes in pH and oxygen status can affect oxidation and precipitation reactions of iron. A number of workers (1, 10) believe that ochre formation occurs as a result of microbial oxidation by the bacteria belonging to the genera Gallionella, Sphaerotilus, Thiobacillus, Thiothrix, and Metallogenium. According to Petersen (9) iron precipitation is neither strictly chemical nor biological. He suggests that soil organic matter is involved in the dissolution and reprecipitation of iron by virtue of its complex forming properties.

Whatever the mechanism of iron precipitation, the accumulation of ochre deposits in the drains directly affects drain performance. The precipitates may impede drainage by clogging drain openings and reducing flow due to deposition inside the drains. From observations at Celeryville, sediment deposition seems to be the major source of impediment. For drain lines with uniform grade and relatively high flow rates, some precipitates in the drainage water may be transported from the drains as a dilute suspension. During low flow rates the precipitates may settle in the drains as a viscous sludge and become dewatered during periods of no flow. Once this process has started, sludges continue to accumulate and may virtually clog drains in a few years.

EFFECT OF JETTING ON PERFORMANCE OF SEDIMENT-AFFECTED DRAINS

This study was conducted to evaluate drain performance after jetting of sediment-laden drains on Wier Brothers Farm. This site is adjacent to the Ohio Agricultural Research and Development Center's Muck Crops Branch. The drains at this site are 12.5 cm diameter clay tiles installed at an average depth of 90 cm. The laterals run in lengths from 150 to 250 m, spaced 15 m apart, and were installed about 17 years previously. Prior to jetting, the drains were 30 to 50% full of ochreous and organic sediments.

During autumn 1975 the drains were jetted with water by a commercial contractor. To perform the jetting operation, water pressure was maintained at

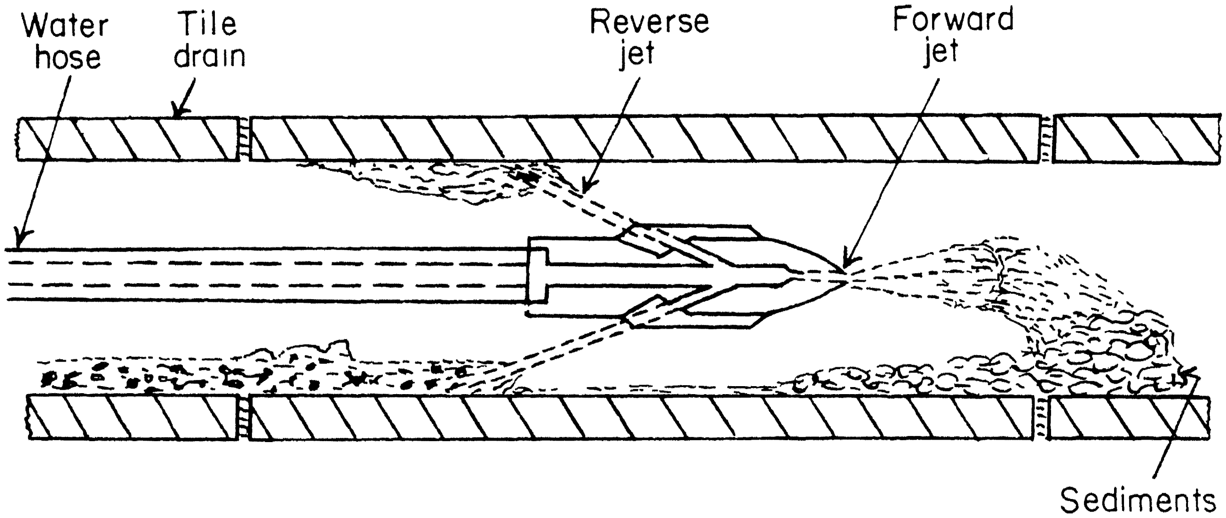

FIG. 4.—A schematic model of cleaning jet nozzle for use in removal of drain sediments.

about 55 to 68 atmospheres from a portable high pressure water pump. The jetting nozzle consisted of one forward jet and five reverse jets inclined at an angle of 15° (Fig. 4). At a flow rate of 3.8 liters per second, the effective nozzle pressure at the end of a 150 m polyethylene hose was about 40 atmospheres.

The authors' observations on drain performance were made 1 year after jetting. For this purpose, an area of about 0.8 hectare that included 5 to 6 drain lines was irrigated with 9 cm of water in order to create a water table above the drains. Before irrigation ceased, water ponded on about 50% of the study area to a depth of 2 to 5 cm. Two days following the irrigation, observation pits about 80 cm deep and 20 cm in diameter were dug directly above the drain, 1 m and 7.5 m (midway) from the drains. Periodic measurements were made during the day on the water table depth and the highest elevation at which seepage occurred in the pits.

There was no water table directly above or at 1 m distant from the drains. The water table was present midway the drains at an elevation of about 50 cm above the drain level. These findings suggest that the drains were removing the excess water and that the soil along the drain boundary was sufficiently permeable for adequate water entry. The excavated drains were found to be relatively free of sediments, containing only 1 cm or so of a reddish-brown dilute suspension. It was concluded that the jetting operation was successful in removing sediments from the drains and, perhaps, in improving the soil permeability adjacent to the drains.

GENERAL DISCUSSION

Intensive cultivation of organic soils over the years has brought about increased decomposition and compaction from tillage and crop management practices. As a result, permeability of soil to water has deteriorated with time. The plow layer of these soils is made up of well decomposed, structureless, organic plant materials. Frequent traffic by heavy machinery used in vegetable crop production often results in a compacted zone of 0-10 cm at the surface. The surface soil usually puddles from the impact of a heavy rain and retards downward infiltration of water. It is not uncommon to see water ponded at the ground surface while the soil below the compact zone is still unsaturated.

To maintain good infiltration following seedbed preparation, some intertillage by suitable implements needs to be evaluated. The authors are currently investigating the infiltration effects of a narrow tillage furrow between crop rows or in the traffic rows. This is accomplished by using small-diameter, chisel shanks mounted behind a tractor.

The low permeability of these soils suggests that subsurface drainage should be supplemented with good surface drainage to avoid prolonged periods of ponding. Subsoiling to improve permeability may be helpful, although the effects of this practice have not been fully evaluated in these soils. Subsoiling may result in short-term improvement until disturbed soil collapses back into original position under wet conditions.

The present state of knowledge does not provide a satisfactory explanation for the complex chemical and biological interactions leading to ochre formation in drains, and effective methods of prevention are unavailable. The accumulation of organic soil materials in the drains seems to result under advanced stages of soil decomposition at the sites. Careful installation of drains at sufficient grade and use of protected surface inlets may be helpful. A graded gravel surround or a protective screen capable of filtering out sediments should be used around the surface inlets. Observations on drain sediments at the Willard Marsh suggest that the major source of clogging is from the mixture of ochre and/or organic sediments inside the drains. Under these situations, jetting will perhaps cleanse out most of the sediments. Jetting of sediment-laden drains may be repeated whenever sediments occupy 30 to 50% of the drains.

In organic soils prone to ochre problems, clogging of drain openings may be reduced by using drains having larger openings rather than narrow slots; however, it may result in more organic sediments moving into the drains. The effect of different drain opening sizes on ochre and organic sediment accumulation in drains is also being investigated at the Willard Marsh.

SUMMARY

Drainage impediments in cultivated organic soils were evaluated at four selected sites by field inspection of drains and laboratory analysis on soil, ground water, and drain sediments. The hydraulic conductivity of the soils was determined *in situ* while undisturbed soil cores were used to measure other soil physical properties.

The soils have a highly decomposed plow layer with approximately 75% organic content, a saturation moisture content by volume of 0.75 cm^3/cm^3, and a bulk density of about 0.41 g/cm^3. The subsoil is partially decomposed and has approximately 85% organic content, a saturation moisture content of 0.95 cm^3/cm^3, and a bulk density of about 0.16 g/cm^3. The surface soil is structureless, puddles during heavy rains, and restricts downward infiltration. A compact soil layer (pan) often develops below the seedbed zone from repeated traffic by heavy machinery. The hydraulic conductivity of the subsoil is quite low and ranges from 0.03 to 1.1 cm/hour.

The elemental composition of soils from the four sites is nearly similar. However, there are differences in the degree of decomposition. Soil at Site 1 is the least decomposed and there is essentially no sediment in drains at this site. Soils at Sites 2, 3, and 4 have a higher degree of soil decomposition and there are appreciable amounts of sediments in drains at these sites. All sites show a marked increase in the amounts of reduced iron below drain depth. Ochreous drain sediments are a common occurrence at Site 2, and amounts of reduced iron in the soil and ground waters are also highest at this site.

Black organic sediments are a mixture of organic and mineral materials approximately similar in composition to the soil surrounding the drains. An exception is noted for the reddish-brown sediments at Site 2 that show distinctly higher iron contents. No practical management methods are known to prevent formation of ochre in drains. Mechanical flushing of drains with a high pressure jetting nozzle was successful in removing a mixture of soil and ochreous drain sediments.

LITERATURE CITED

1. Bloomfield, C. 1972. The Oxidation of Iron Sulphides in Soils in Relation to the Formation of Acid Sulphate Soils and of Ochre Deposits in Field Drains. J. Soil Sci., 23:1-16.
2. Boersma, L. 1965. Field Measurement of Hydraulic Conductivity Above a Water Table. *In* C. A. Black (ed.), Methods of Soil Analyses, Part I. Amer. Soc. of Agron., Madison, Wis., Agron., 9:242-252.
3. Ford, H. W. 1973. Obstacles to Water Control in Florida Citrus Groves. Paper presented at International Citrus Congress, Murcia, Spain.
4. Grass, L. B. and A. J. MacKenzie. 1972. Restoring Subsurface Drain Performance. J. Irrigation and Drainage Div., ASCE, 98:97-106.
5. Hundal, S. S., G. S. Taylor, and G. O. Schwab. 1977. Ochre and Subsurface Drainage in Cultivated Organic Soils of Willard Marsh, Ohio. Trans., Amer. Soc. Agri. Engr., 20(3):489-492.
6. Ignatieff, V. 1941. Determination and Behavior of Ferrous Iron in Soils. Soil Sci., 51: 249-263.
7. Levesque, M. and H. Danel. 1977. Fiber Content, Particle-size Distribution and Some Related Properties of Four Peat Materials in Eastern Canada. Can. J. Soil Sci., 57:187-195.
8. Luthin, J. N. 1957. Drainage of Agricultural Lands. Amer. Soc. of Agron., Madison, Wis., Agron., 7.
9. Petersen, L. 1966. Ochreous Deposits in Drain Pipes. Acta Agri. Scand., 16:120-128.
10. Spencer, W. F., R. Patrick, and H. W. Ford. 1963. The Occurrence and Cause of Iron Oxide Deposits in Tile Drains. Soil Sci. Soc. Amer. Proc., 27:134-137.
11. Starkey, R. L. and H. O. Halvorson. 1927. Studies on the Transformations of Iron in Nature. II. Concerning the Importance of Microorganisms in the Solution and Precipitation of Iron. Soil Sci., 24:381-402.

The State Is the Campus for Agricultural Research and Development

Ohio's major soil types and climatic conditions are represented at the Research Center's 12 locations.

Research is conducted by 15 departments on more than 7000 acres at Center headquarters in Wooster, eight branches, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Jackson Branch, Jackson, Jackson County: 502 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres